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N66-16146
(ACCESSION NUMBER)
(THRU) 1
16
(PAGES)
(CODE)
30
(NASA CR OR TMX OR AD NUMBER)
(CATEGORY)
FACILITY FORM 602

Translation of "Yeshche raz ob izmenenii bleska sputnika 'Ekho-I'". Byull. stantsii opticheskogo nablyudeniya Iskusstvennykh Sputnikh Zemli, Akademiya Nauk SSSR, No.36, pp.23-9, 1963.

GPO PRICE $

CFSTI PRICE(S) $

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON DECEMBER 1965

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BRIGHTNESS VARIATION OF THE ECHO I SATELLITE */23

M.V.Bratiychuk and G.V.Moskaleva

Photometric curves of the satellite "Echo I" obtained photographically at the Station 1055 (Uzhgorod) are given. A short period of the brightness variation of "Echo I" lasting about several seconds is discovered. A preliminary attempt is made to explain this phenomenon from the character of the form of the reflecting surface of the object.

Station No.1055 (Uzhgorod) has obtained a large number of photographs of the transits of the Echo I satellite, by the following method: the photographing was started with a prolonged exposure, which made possible a photometric investigation of the brightness variation and the detection of the short period of this variation - a period which proved to be shorter than that indicated in the literature (Bibl.1, 2, 3).

Certain authors came to the conclusion that the brightness variation of Echo I had stopped (Bibl.1). On a careful analysis of the available findings we found this conclusion to be untrue. In actual fact, the brightness of Echo I apparently has been varying all the time, but the character of this variation is inconstant. At times the variation proceeded extremely slowly, with such a smooth transition from the maximum to the minimum brightness that it could not be visually detected. The same can be said of the methods of photometry if applied to short segments of the satellite trajectory.

In the present article an attempt is made to explain the nature of the

* Numbers in the margin indicate pagination in the original foreign text.

brightness variation of Echo I as a function of the configuration of its surface and the position of its axis of rotation relative to the observer.

As is known, a man-made object, on achieving an orbit, begins to revolve about its axis, with the axis of rotation being in precession or sometimes even "wobbling"; this has been described in several studies based on observations made with the aid of Soviet artificial earth satellites (Bibl.4). We will discuss here several instances of the spin of bodies of different shape with different orientation of the axis of rotation relative to the observer (in all cases we assume that the observer views the reflecting sector of the surface in its "full phase").

Figure 1 shows a projectile-shaped body; part b of the body is in the shadow. In case 1, the line of sight is at right angles to the axis of rotation and to the longitudinal section of the body. In this case, the brightness variation will be of the form shown by the adjoining curve. The sector c of the projectile surface reflects the maximum light in the direction of the observer, while the sector a reflects less light (shallow minimum) and the sector b is completely unreflecting (principal minimum). In case 2, the observer is looking along the axis of rotation of the body and thus will not see the brightness variation. In this case, the adjoining curve is parallel to the time axis. In case 3, the axis of rotation is inclined to the line of sight at an angle φ, where $0^\circ < \varphi < 90^\circ$. Here, the brightness variation will be a function of φ, and the slope of the curve will also differ, depending on φ (one of the possible curves is shown in the graph).

In Fig.2 the body surface is an ideal sphere. Light is reflected equally in all directions. Whatever the position of the axis of rotation and whatever the direction of the line of sight, there will be no variation in bright- /24 ness.

Figure 3 shows a spherical body constructed of discrete two-dimensional polyhedrons each of which reflects light like a plane mirror. Since a parallel

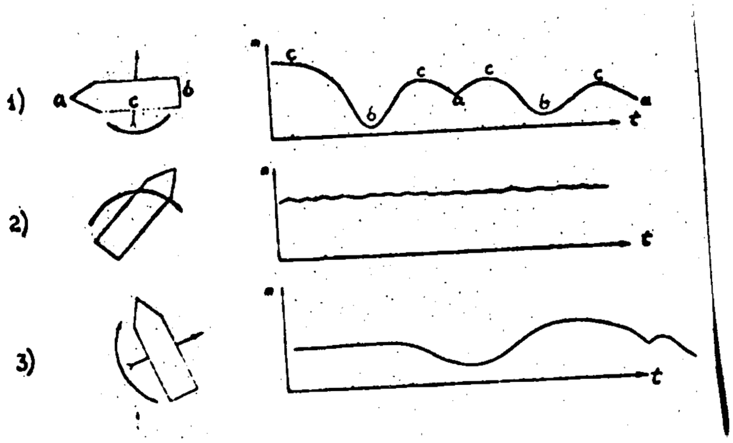

Fig.1

beam from the sun strikes the body surface, each plane mirror polyhedron will transmit to the observer its own parallel beam of reflected light. The observer will see a rapid brightness variation, of the type shown by the curve. Then the

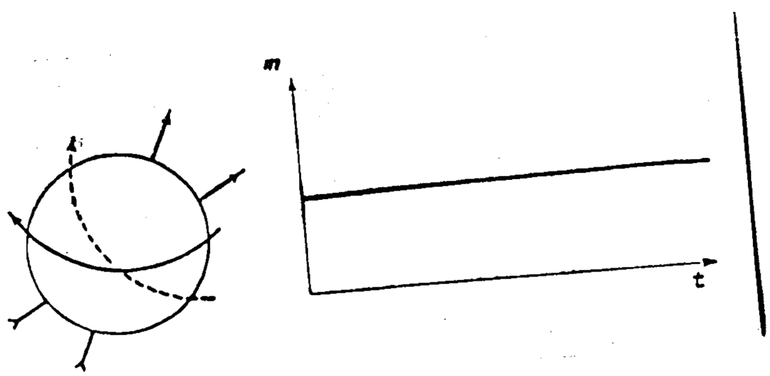

Fig.2

maximum brightness will correspond to the position of the polyhedron in which it reflects light directly toward the observer. In this case, as in the preceding case, the brightness curve will retain a fixed slope, no matter what the position of the axis of rotation with respect to the line of sight might be.

The spherical body surface in Fig.4 consists of discrete curved segments tapering off at both ends. The points at which these ends converge will be termed the poles of the body.

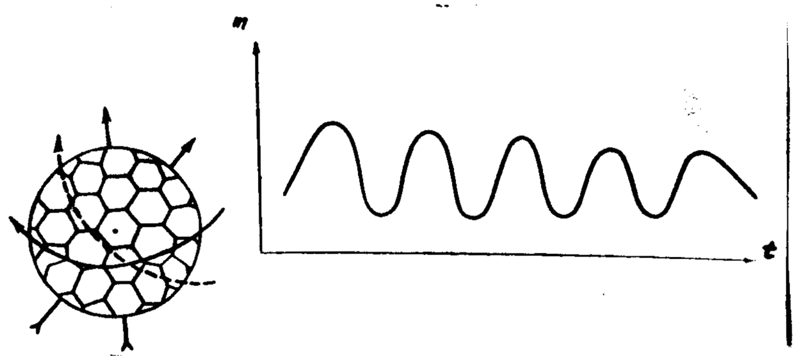

Fig.3

Case 1): The axis of rotation lies in the plane of the equator of the body; the line of sight is at right angles to the plane of the paper. The observer

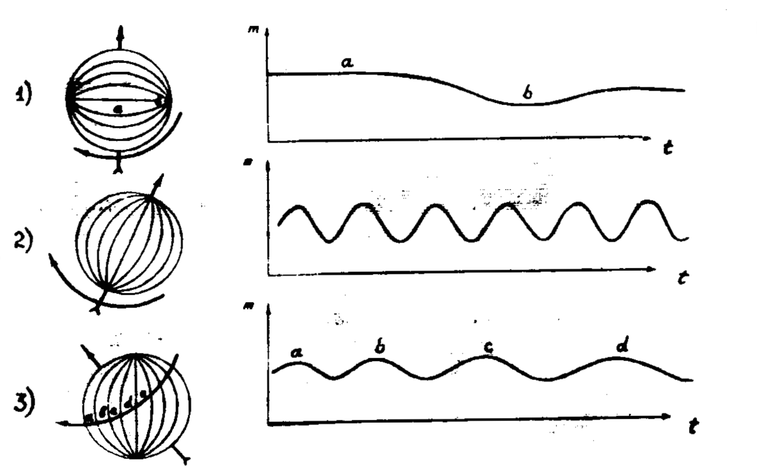

Fig.4

receives reflected light from the sectors a and b, which reflect as spherical mirrors. Since the junctions converge in the sector b, a minimum is observed during the transit of this sector across the line of sight. In the course of a single complete revolution of the body, two brightness minima and two maxima are observed.

Case 2): The axis of rotation goes through the body poles, and the line of sight is at right angles to the plane of the paper. As the object spins, each individual strip will reflect an identical amount of light toward the observer, each junction will scatter light to the sides. The strips cause the brightness maxima, and their junctions are responsible for the minima. During a single complete revolution of the body about its axis, n maxima and n minima will be observed (n = number of strips).

Case 3): The axis of rotation is inclined to the plane of the equator, and the line of sight is at right angles to the plane of the paper. As the object spins, the broad and the narrow parts of the strips a, b, c, d, e are alternately turned toward the observer. Accordingly, alternating broad and narrow maxima and minima will be observed on the curve of the brightness variation.

The above discussion of several different shapes of artificial celestial bodies demonstrates that the curves of their brightness variation indicate to some extent the particular structure of their surface. Moreover, this shows that the term "period of brightness variation" should be used with great caution. At any rate, the "period of brightness variation" does not always correspond to the period of revolution of the body about its axis. For example, in the cases shown in Figs.3 and 4 (example 2) the period of revolution of the body about its axis can be determined as a function of the brightness of the body /25 only if the number of segments constituting the body surface is known. Figures 5, 6, 7 present the most characteristic curves of brightness variation of Echo I. Below each curve we give the number of the photographic negative and the date and time (UT) when obtained. The readings of the galvanometer, while taking measurements with the MF-2 microphotometer, are plotted along the ordi-

/26

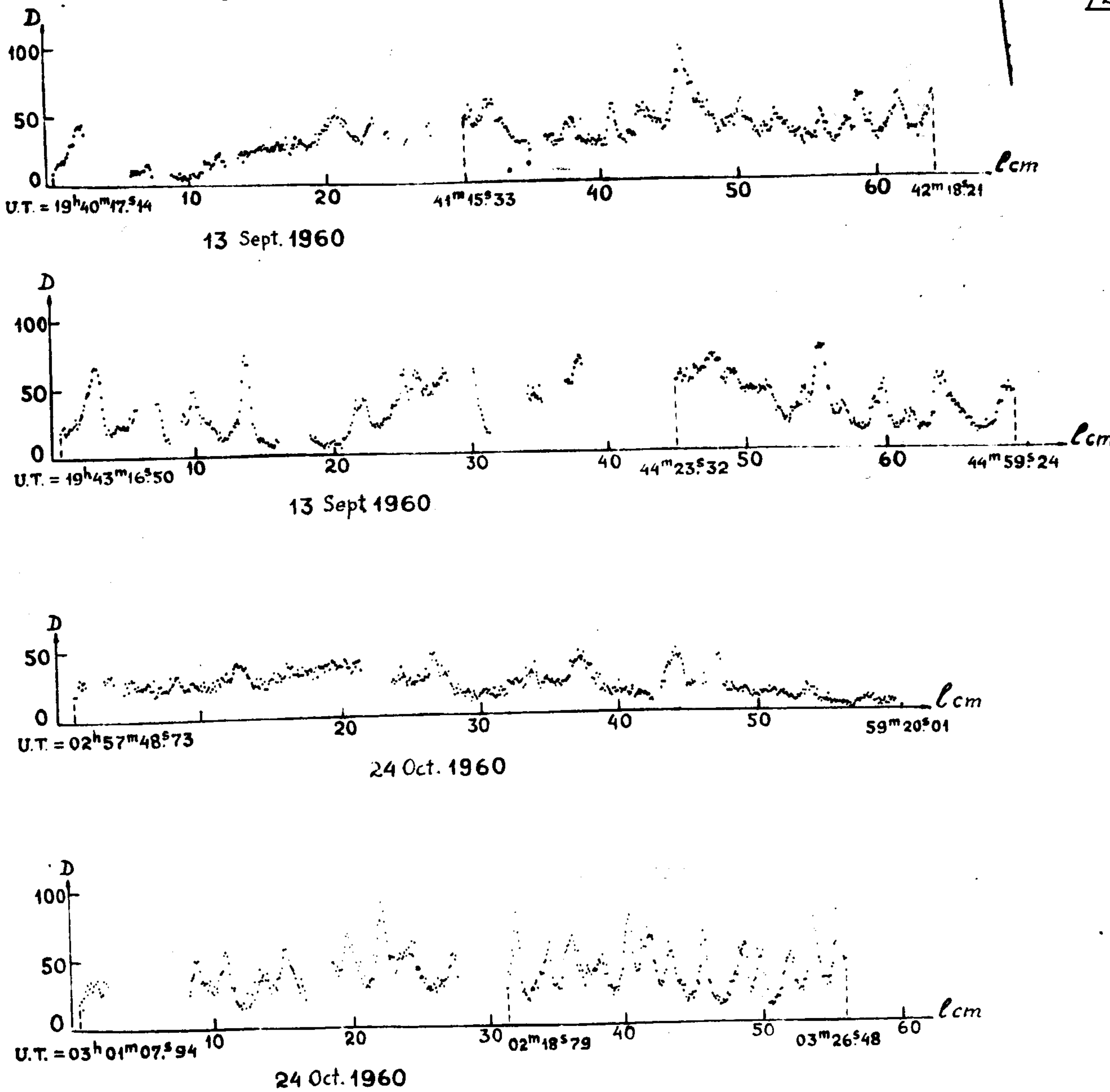
D
100
50
0
U.T. = 19h40m17.s14
10
20
41m15s33
40
50
60
42m18s21
ℓcm
13 Sept. 1960
D
100
50
0
U.T. = 19h43m16s50
10
20
30
40
44m23s32
50
60
44m59s24
ℓcm
13 Sept 1960
D
50
0
U.T. = 02h57m48s73
20
30
40
50
59m20s01
ℓcm
24 Oct. 1960
D
100
50
0
U.T. = 03h01m07s94
10
20
30
02m18s79
40
50
03m26s48
60
ℓcm
24 Oct. 1960

Fig.5

/27

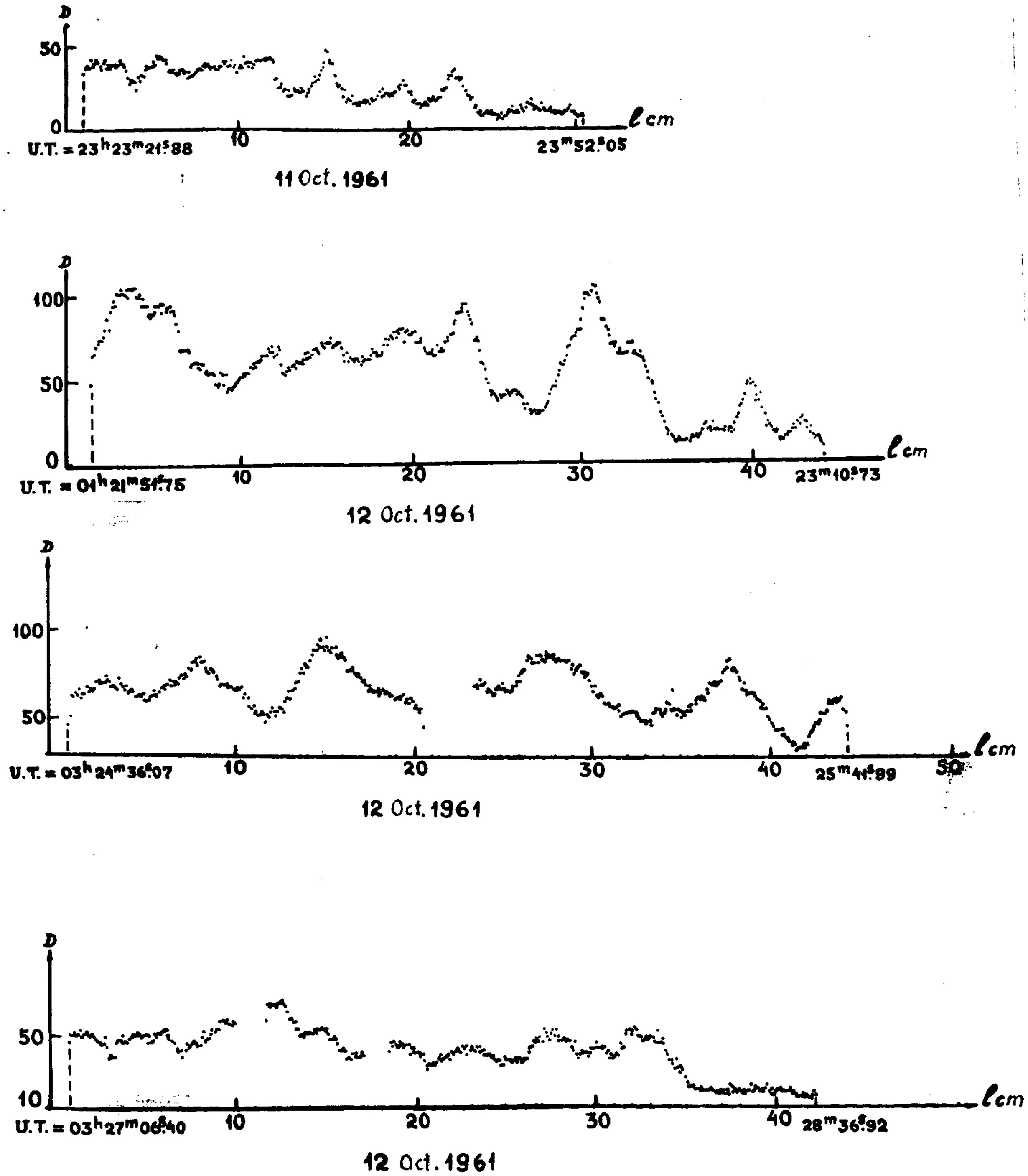
D
50
0
U.T. = 23h23m21s88
10
20
23m52s05
l cm
11 Oct. 1961
D
100
50
0
U.T. = 01h21m51s75
10
20
30
40
23m10s73
l cm
12 Oct. 1961
D
100
50
U.T. = 03h24m36s07
10
20
30
40
25m41s89
50
l cm
12 Oct. 1961
D
50
10
U.T. = 03h27m06s40
10
20
30
40
28m36s92
l cm
12 Oct. 1961

Fig.6

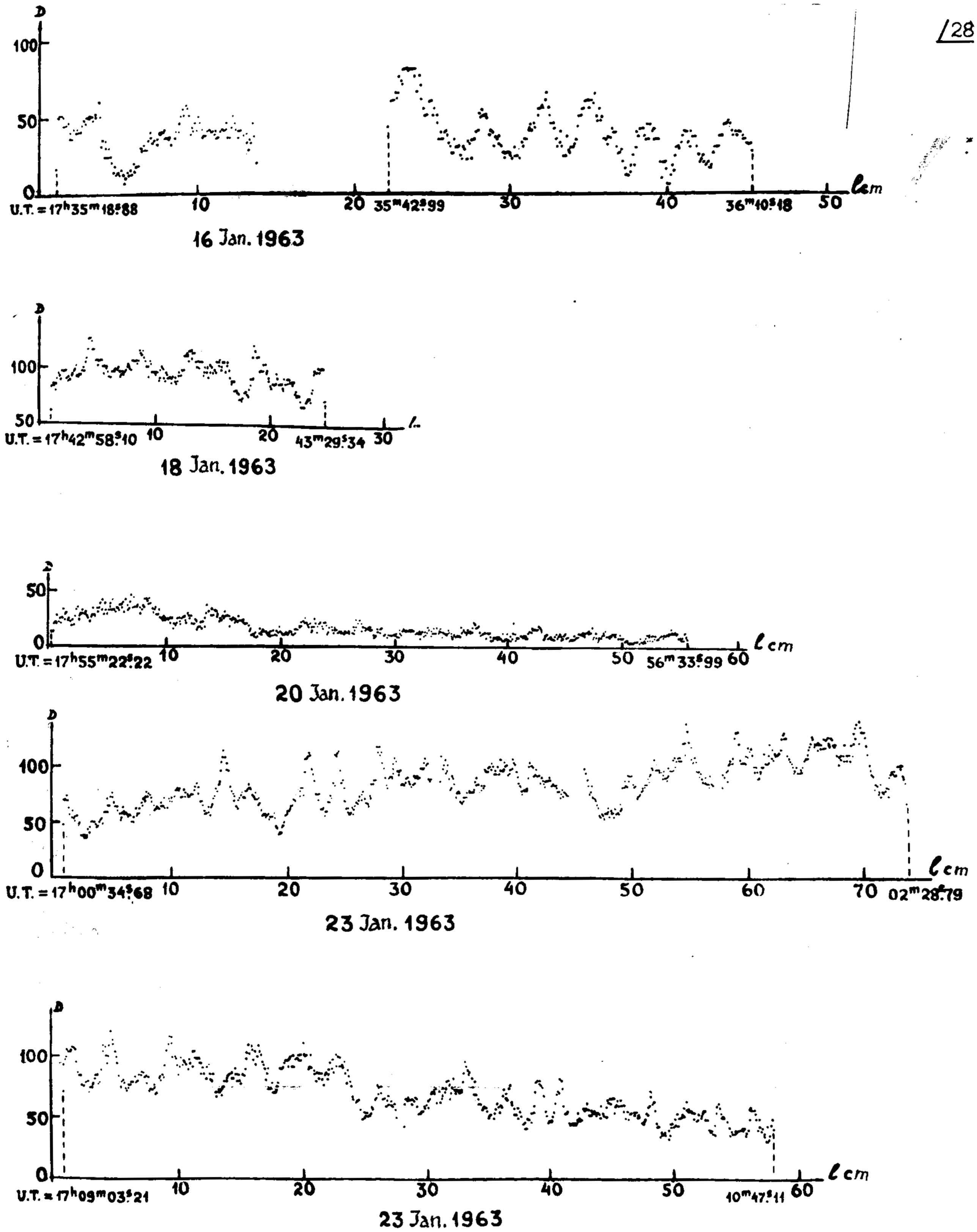
D
100
50
0
U.T. = 17h35m18s88
10
20
35m42s99
30
40
36m40s18
50
ℓcm
16 Jan. 1963
D
100
50
U.T. = 17h42m58s10
10
20
43m29s34
30
ℓ
18 Jan. 1963
D
50
0
U.T. = 17h55m22s22
10
20
30
40
50
56m33s99
60
ℓcm
20 Jan. 1963
D
100
50
0
U.T. = 17h00m34s68
10
20
30
40
50
60
70
02m28s79
ℓcm
23 Jan. 1963
D
100
50
0
U.T. = 17h09m03s21
10
20
30
40
50
10m47s11
60
ℓcm
23 Jan. 1963

Fig.7

nate, while the time is plotted along the abscissa.

Figure 5 shows the curves of brightness variation plotted from the photographs obtained in 1960; Fig.6, in 1961; and Fig.7, in 1963. The slope of the curves in Fig.6 distinctly differs from that of the curves in Figs.5 and 7.

On the third curve in Fig.7, the brightness variation is almost negligible.

The Table below presents "periods of brightness variation", i.e., the time intervals between successive maxima of this variation.

TABLE OF PERIODS

[illegible]	24 Oct.60	11 Oct.61 U.T. 23^h23^m	16 Jan.61 U.T. 17^h35^m	23 Jan.63 U.T. 17^h00^m	23 Jan.63 U.T. 17^h09^m
периоды:	периоды:	периоды:	периоды:	периоды:	Period:
$11^s.10$	$3^s.79$	$2^s.97$	$5^s.68$	$5^s.16$	$5^s.10$
5.46	11.22	4.60	4.41	4.64	4.08
3.82	5.53	3.17	3.60	2.58	3.74
5.46			4.18	3.96	3.06
7.64	24 Oct.60	12 Oct.61	3.02	3.78	5.61
4.55	U.T. 03^h01^m	U.T. 01^h21^m	3.13	8.77	2.55
6.01	Period:	Period:	4.18	4.30	6.29
5.10	$4^s.86$	$5^s.58$	1.00	6.19	5.10
4.91	4.32	16.74	6.89	2.41	5.78
	5.94	13.95		4.72	3.74
13 Sep.60	3.24	6.51	18 Jan.63	2.14	1.97
U.T. 19^h43^m	7.83		U.T. 17^h42^m	1.53	3.35
периоды:	6.75	12 Oct.61	периоды:	1.38	6.30
$5^s.75$	4.32	U.T. 03^h24^m	$5^s.78$	2.30	4.92
1.95	3.24	Period:	5.15	3.52	3.35
2.40	5.67	$8^s.05$	5.15	4.28	4.14
2.40	5.94	11.11	4.46	1.48	4.33
1.95	4.59	9.44		2.43	5.91
2.10	6.38	16.48		1.48	5.71
4.50	4.84			3.24	4.92
6.00	5.50	12 Oct.61		2.02	5.32
7.20	2.85	U.T. 03^h27^m		3.51	
	4.94	Period:		4.46	
	3.99	$7^s.11$			
		3.65			
		6.27			
		8.81			
		10.40			
		10.40			

It can be seen from this Table that the periods of brightness variation cannot be accurately defined. It is clear, however, that these periods are extremely short, of the order of a few seconds. Several curves for determining a "period" of this order have been published (Bibl.3). Assuming a period of 4 - 5 sec, the complete period of revolution of the satellite about its axis will be $4 \times 82 = 328$ sec or $5 \times 82 = 410$ sec, i.e., 5 min 28 sec or 6 min 50 sec or roughly 6 min [according to another report (Bibl.5), the surface of the Echo I satellite has been assembled from 82 segments]. It is not possible to visually determine with greater exactitude the period of revolution of the satellite, owing to the scattering of points on the curve of brightness variation, apparently caused by distortions on the reflecting cover. If each segment of the satellite reflects as a mirror, then different slopes of the brightness variation curve and different periods will be observed, depending on the position of the satellite axis of rotation with respect to the line of sight (cf. Fig.4).

Thus, the photometering of the photographic tracks of different objects may reveal much about the objects themselves. To this end, the station in Uzhgorod is continuing its photometering of different objects and plans to develop special observational methods.

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Received: May 4, 1963.